CLAIMS

1. A photonic device, comprising:

a silicon semiconductor based superlattice that includes a plurality of layers that form a plurality of repeating units, wherein at least one of the layers in the repeating unit is an optically active layer with at least one species of rare earth ion.

2. The device of claim 1, further comprising:

one or more cladding layers coupled to the superlattice configured to guide and propagate an optical mode that overlaps at least a portion of the superlattice.

3. The device of claim 1, further comprising:

first and second electrodes , wherein at least a portion of the superlattice is positioned between the first and second electrodes.

4. The device of claim 1, further comprising:

a least one electrode that extends from an exterior of the superlattice to an interior of the superlattice.

5. The device of claim 1, further comprising:

at least one electrically doped p- or n-type layer coupled to the superlattice.

6. The device of claim 1, wherein the optically active layer is sandwiched between doped p- or n-type layers.

7. The device of claim 1, further comprising:

a mode size converter configured to be coupled to an optical fiber and the superlattice.

8. The device of claim 1, wherein the mode size converter is a tapered waveguide structure.

9. The device of claim 1, wherein the repeating units are periodic.

10. The device of claim 1, wherein the repeating units have uniform layer constructions.

11. The device of claim 1, wherein the repeating units have non-uniform layer constructions.

12. The device of claim 1, wherein the rare earth ion has an energy level configuration that is determined by the symmetry of a crystal field produced by the superlattice structure.

13. The device of claim 1, wherein a crystal field of the device is configured to be spatially variable by altering composition of layers.

14. The device of claim 1, wherein a crystal field of the device is configured to be spatially variable by altering thick nesses of layers in the device along the growth direction.

15. The device of claim 1, wherein a thickness of the repeating units varies as a function of distance along a superlattice growth direction.

16. The device of claim 1, wherein the thickness of each repeating unit is the same and a thickness of the individual layers of the repeating units varies as a function of distance substantially along at least of

a superlattice growth direction and perpendicular to the superlattice growth direction.

17. The device of claim 1, wherein a composition of the repeating units varies as a function of distance along a superlattice growth.

18. The device of claim 1, wherein at least one of the layers is amorphous.

19. The device of claim 1, wherein at least a portion of the active region layer is a narrow band gap semiconductor relative to other layers in a repeating unit.

20. The device of claim 1, wherein at least a portion of the active region layer is a wide band gap semiconductor relative to other layers in a repeating unit.

21. The device of claim 1, further comprising at least one spacer layer between two adjacent repeating units.

22. The device of claim 21, wherein the spacer layer varies in thickness along a growth direction.

23. The device of claim 1, wherein the repeating units includes ultra-thin layers.

24. The device of claim 23, wherein the ultra-thin layers have a thickness of 1000 Å or less.

25. The device of claim 23, wherein the ultra- layers are thin enough to be non-bulk material layers.

26. The device of claim 1, wherein each repeating unit has two or more layers.

27. The device of claim 1, wherein each repeating unit is repeated N times, where N is a whole or partial integer of monolayers.

28. The device of claim 1 wherein each repeating unit has at least two layers made with different compositions.

29. The device of claim 1, wherein each repeating unit has at least two layers with different thicknesses.

30. The device of claim 1, wherein at least a portion of the repeating units have different thicknesses.

31. The device of claim 1, wherein at least a portion of layers in a repeating unit have different thick nesses.

32. The device of claim 1 wherein each repeating unit has three layers made of with different compositions.

33. The device of claim 1, wherein each repeating unit has a Si layer that includes the rare earth.

34. The device of claim 1, wherein each repeating unit has a silicon germanium layer.

35. The device of claim 1, wherein each repeating unit has a silicon oxide layer.

36. The device of claim 1, wherein each repeating unit has an oxygen-doped silicon layer.

37. The device of claim 1, wherein each repeating unit has a rare earth silicide layer.

38. The device of claim 1, wherein each repeating unit has a rare earth silicon germanium layer.

39. The device of claim 1, wherein each repeating unit includes an electrically doped p- or n-type layer.

40. The device of claim 1, further comprising:

at least one crystal growth modifier included in at least one layer of each repeating unit.

41. The device of claim 40, wherein the growth modifier is selected from at least one of C, H, O, N, P, As, B, Sb, Co, Ni, Ir, Sn and Pb.

42. The device of claim 1, wherein the rare earth ion is selected from at least one of Er, Pr, Nd, Eu, Ho, Pm, Tb, Sm, Tm and Yb.

43. The device of claim 1, wherein the rare earth ion is Er.

44. The device of claim 1, wherein the active region layer includes at least two different rare earth ions.

45. The device of claim 1, wherein the multi-layer silicon based superlattice is positioned on a silicon substrate.

46. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on a silicon substrate.

47. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on an (001)-oriented surface of the silicon substrate.

48. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on a (111)-oriented surface of the silicon substrate.

49. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on at least one h, k and l-oriented surface of the silicon substratem wherein h, k, and l are sets of integers that are crystallographic Miller indices notation..

50. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on one of a geometrically and compositionally patterned silicon substrate.

51. The device of claim 1 wherein the multi-layer silicon based superlattice is deposited in a superlattice growth direction and has a laterally ordered structure substantially perpendicular to a growth direction.

52. The device of claim 1 wherein the multi-layer silicon based superlattice is deposited in a superlattice growth direction and has a laterally ordered structure substantially perpendicular to a growth direction.

53. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on a pseudo-substrate buffer layer with a lattice constant that is different from a lattice constant of an underlying bulk silicon substrate.

54. The device of claim 1, wherein the multi-layer silicon based superlattice is grown on a silicon-on-insulator wafer.

55. The device of claim 1, wherein the active region layer has a lattice constant that is less than a lattice constant of an underlying bulk silicon substrate.

56. The device of claim 1, wherein the active region layer has a lattice constant that is less than a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is different from a lattice constant of an underlying bulk silicon substrate.

57. The device of claim 1, wherein the active region layer has a lattice constant that is equal to a lattice constant of an underlying bulk silicon substrate.

58. The device of claim 1, wherein the active region layer has a lattice constant that is equal to a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is different from a lattice constant of an underlying bulk silicon substrate.

59. The device of claim 1, wherein the active region layer has a lattice constant that is greater than a lattice constant of an underlying bulk silicon substrate.

60. The device of claim 1, wherein the active region layer has a lattice constant that is greater than a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is different from a lattice constant of an underlying bulk silicon substrate.

61. The device of claim 46, wherein at least one layer in a repeating unit has a lattice constant that is sufficiently different from a lattice constant of the substrate to be substantially in a state of elastic mechanical stress.

62. The device of claim 53, wherein at least one layer in a repeating unit has a lattice constant that is sufficiently different from a

lattice constant of the pseudo-substrate buffer layer to be substantially in a state of elastic mechanical stress.

63. The device of claim 46, wherein at least two of layers of repeating units have substantially equal and opposite mechanical strain energy and strain states and each repeating unit is substantially lattice matched to the silicon substrate.

64. The device of claim 46, wherein at least two of layers of repeating units have substantially equal and opposite mechanical energy and strain states and each repeating unit is substantially lattice matched to the pseudo-substrate buffer layer.

65. The device of claim 13, wherein the crystal field is modified by a strain field induced by lattice mismatched layers in a repeating unit.

66. A wavelength selective optical device, comprising

a silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion; and

a filter coupled to the superlattice.

67. An optical switch, comprising:

a silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion; and

an optical waveguide.

68. An optical device, comprising:

a silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion;

a silicon containing layer positioned on a surface of the superlattice; and

at least one transistor positioned on a surface of the silicon containing layer.

69. A nonlinear optical device comprising:

a plurality of adjacent silicon based superlattice structures including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion;

wherein each adjacent superlattice structure is gown in an alternating fashion to create a periodic variation in a refractive index

70. A tunable laser system, comprising:

first and second reflectors defining a resonator;

a silicon based superlattice positioned between the first and second reflectors, the silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion; wherein the repeating units are periodic and a period of the repeating units is selected to produce a desired output wavelength.

a wavelength tuning member coupled to the laser;

a temperature sensor coupled to the laser; and

a control loop coupled to the temperature sensor and the tuning member, wherein in response to a detected change in temperature the control loop sends an adjustment signal to the tuning member and the tuning

member adjusts a voltage or current supplied to the laser to provide a controlled output beam of selected wavelength.

71. An optical receiver, comprising:

at least one p-doped layer;

at least one n- doped layer;

a silicon based superlattice positioned between the at least one p-doped layer and the at least one n-doped layer; the silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion; and

at least two electrodes coupled to the at least one p-doped layer and the at least one n-doped layer of p-doped layer.

72. The receiver of claim 71, wherein at least one p-doped layer and the at least one n- doped layer are made substantially of silicon.

73. A semiconductor edge-emitting laser,

first and second reflectors defining a resonator;

a silicon based superlattice positioned between the first and second reflectors, the silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion;

a confinement region that includes at least two electrodes.

74. The laser of claim 73, further comprising:

cleaved or etched facets.

75. The laser of claim 73, wherein the confinement region is positioned in a direction substantially parallel to an optical output direction of the laser.

76. A laser assembly, comprising:

first and second reflectors defining a laser resonator;

a silicon based superlattice positioned between the first and second reflectors, the silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion; wherein the repeating units are periodic, and a period and composition of the repeating units is selected to produce a desired output wavelength.

77. The assembly of claim 76, wherein the first reflector is a distributed Bragg reflector.

78. The assembly of claim 76, further comprising:

an optical amplifier.

79. A vertical cavity surface emitting semiconductor laser, comprising:

first and second reflectors defining a resonator;

a silicon based superlattice positioned between the first and second reflectors and confined to a substantially circular region whose diameter matches a single mode diameter of the laser, the silicon based superlattice including a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion and the repeating units are periodic, with a period and composition of the repeating units selected to produce a desired output wavelength.

80. The laser of claim 79, wherein the first reflector is a distributed Bragg reflector.

81. An optical switch, comprising:

a first optical waveguide with biasing electrodes;

a second optical waveguide with biasing electrodes, at least one of the first and second optical waveguides including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion;

a coupling member that couples the first and second waveguides; and

control circuitry coupled to the first and second waveguides.

82. The switch of claim 81, further comprising:

first and second outputs coupled to the first and second waveguides.

83. The optical switch of claim 82, wherein the control circuitry is configured to selectively bias the first and second optical waveguides to switch optical signals to the first or second outputs.

84. The optical switch of claim 81, wherein the coupling member couples the first and second waveguides to a third waveguide.

85. The optical switch of claim 81, wherein the optical switch is a plurality of optical switches that form an N-to-N optical switch.

86. A modulator, comprising:

a first optical waveguide with biasing electrodes;

a second optical waveguide with biasing electrodes, at least one of the first and second optical waveguides including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, the first and second waveguides having equal light paths;

a coupling member that couples the first and second waveguides;

at least one output coupled to the first and second waveguides; and

control circuitry coupled to the first and second waveguides to induce a refractive index change in one of the light paths and cause destructive interference between the light paths upon recombination of light at the output.

87. An add/drop multiplexer, comprising:

a first waveguide;

a second waveguide;

a ring waveguide including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion; and

control circuitry coupled to ring waveguide, the control circuitry configured to couple light from the first waveguide to the ring waveguide and then to the second waveguide.

88. An all optical N-to-N cross-connect comprising:

a first plurality of parallel waveguides;

a second plurality of planar parallel waveguides, positioned substantially orthogonal to the first plurality of waveguides;

a third plurality of curved waveguides positioned at overlap intersection points between the first and second pluralities of waveguides, each of a waveguide of the third plurality of curved waveguides including a

silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion; and

control circuitry coupled to selectively bias gain or loss in the superlattices of the third plurality of curved waveguides to couple light from one of the first plurality of waveguides into one of the second plurality of waveguides.

89. The cross-connect of claim 88, wherein at least a portion of the superlattice has a region that is optically active

90. The cross-connect of claim 88, wherein at least a portion of the superlattice has a region that is electrically excitable to emit or absorb optical radiation.

91. The cross-connect of claim 88, wherein at least a portion of the superlattice has a region that detects optical radiation.

92. An optical wavelength converter, comprising:

a first optical waveguide;

a second optical waveguide, each of the first and second optical waveguides including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, superlattice including biasing electrodes to induce optical gain or loss within the first and second waveguides;

at least one coupling member coupling the first and second waveguides;

a first optical input signal and a second optical input signal coupled to the first and second optical waveguides; and

wherein the superlattices of the first and second optical waveguides are biased to provide gain for the first optical signal and transfer a modulation from the first optical input signal to the second optical input signal by at least one of cross-phase or cross-gain modulation.

93. A dynamic gain equalizer, comprising:

an arrayed waveguide grating including at least two resonant cavities coupled by a plurality of curved waveguides, each of a waveguide including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, wherein lengths of the waveguides vary by a fraction of a wavelength of light propagating within the waveguides; and

control electronics to selectively bias each waveguide and produce a predetermined gain or loss to each wavelength in a spectrum of wavelengths exiting the arrayed waveguide grating.

94. An integrated transponder, comprising:

a substrate;

at least one a p-doped layer and an n- doped layer

a silicon based superlattice including a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion and the superlattice is formed on the substrate; and

electronic components integrated in the substrate and superlattice, the electronic components configured to provide at least one of control, filtering, clock recovery, signal detection, noise suppression and electronic signal processing of electrical signals generated by interaction between an optical input signal and superlattice and producing an optical output signal.

95. A dynamic optical multiplexer/demultiplexer, comprising of:

a photonic band gap region forming dispersive member that spatially separates an input wavelength division multiplexed signal into a plurality of spatially separated individual wavelengths;

a plurality of outputs;

a plurality of waveguides coupled to the plurality of outputs, at least a portion of the plurality of waveguides having a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, the superlattice including electrical circuitry to selectively bias the superlattice for gain or loss;

a coupling device that combines the spatially separated waveguides into a single optical waveguide .

96. A photonic integrated circuit, comprising:

a plurality of waveguides, at least a portion of the plurality of waveguides having a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion;

at least one optical switch;

electronics coupled to the plurality of waveguides; and

a substrate, wherein the plurality of waveguides, at least one optical switch and electronics are all integrated on the substrate.

97. An optical intensity modulator, comprising:

a plurality of waveguides, at least a portion of the plurality of waveguides having a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion; and

electronics coupled to the plurality of waveguides, the electronics and plurality of waveguides being configured to modulate an input optical signal and produce a modulated output optical signal.

98. An optical modulator, comprising:

a plurality of waveguides, at least a portion of the plurality of waveguides having a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion; and

electronics coupled to the plurality of waveguides, the electronics and plurality of waveguides being configured to vary at least one of refractive index and loss of the waveguide to modulate a phase of an input optical signal and produce a modulated output optical signal.

99. The optical phase modulator of claim 98, wherein a second optical input signal directly modulates the output optical signal.

100. An optical transistor comprising:

a modulator, including

a waveguide, at least a portion of the waveguide having a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion,

electronics coupled to the waveguide, the electronics and waveguide being configured to modulate an input optical signal and produce a modulated output optical signal, and

an optical receiver coupled to the modulator, the optical receiver including,

at least one p-doped layer,

at least one n- doped layer,

a silicon based superlattice positioned between the at least one p-doped layer and the at least one n-doped layer; the silicon based superlattice including a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, and

at least two electrodes coupled to the at least one p-doped layer and the at least one n-doped layer of p-doped layer; wherein the receiver converts said optical signals received from the modulator into electrical signals and drives the modulator.

101. The optical transistor of claim 100, further comprising:

a clock recovery circuitry configured to retime and reshape optical pulses.

102. The optical transistor of claim 101, further comprising:

noise filtering circuitry configured to filter noise from the optical pulses input.

103. The optical transistor of claim 101, further comprising:

wherein a first optical input is a broad wavelength spectrum laser that produces a first optical input signal; and

drive circuitry configured to select a laser wavelength and control wavelength conversion.

104. An optical amplifier, comprising:

a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion;

a semiconductor laser diode that produces an output signal with a wavelength in the range of 700 nm and 1700 nm; and

at least two electrodes coupled to the at least one p-doped layer and the at least one n-doped layer of p-doped layer

a laser coupled to the optical receiver, including,

first and second reflectors defining a resonator;

a silicon based superlattice positioned between the first and second reflectors, the silicon based superlattice including a plurality of layers that form a plurality of repeating units, wherein at least one of the layers is an active region layer with at least one rare earth ion;

electrical circuitry coupled to the laser and the optical receiver; and

electronics coupled to the laser and the optical receiver configured to provide at least one of control, filtering and clock recovery, signal detection, noise suppression and electronics signal processing of electrical signals generated by an interaction with an optical input signal and the superlattice of the laser.

108. A silicon semiconductor based superlattice, comprising:

a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, wherein the superlattice forms a portion of a heterojunction bipolar transistor.

109. A silicon semiconductor based superlattice, comprising:

a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, wherein at least a portion of the plurality of layers are interleaved with a plurality of quantum wells.

110. An electrically pumped amplifier, comprising:

a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region

layer with at least one rare earth ion, wherein the layers are ultra-thin epitaxial layers.

111. An optically pumped amplifier, comprising:

a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, wherein the layers are epitaxial layers; and

an optical pump source coupled to the superlattice to optically excite gain within the superlattice.

112. A bipolar transistor, comprising:

a collector including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion, wherein the superlattice has a miniband injector as an emitter region.

113. A reconfigurable optical add drop multiplexer, comprising:

an optical demultiplexer that separates an input optical signal into discrete wavelengths that each propagating in its own waveguide;

an optical multiplexer;

a first plurality of waveguides that couple the demultiplexer and the multiplexer, each of a waveguide of the first plurality including a 1-to-2 optical switch, each switch including a silicon based superlattice with a plurality of layers that form a plurality of repeating units, at least one of the layers being an active region layer with at least one rare earth ion,

a second plurality of waveguides connected to the outputs of the 1-to-2 optical switches; and

electrical control circuitry configured to bias the superlattices and switch light into one of the first or second waveguides.